Description

Lubricating Oil Composition

[Technical Field]

This invention relates to lubricating oil compositions and more particularly to those which have excellent and long-lasting anti-shudder properties and are capable of providing a long fatigue life, suitable for automatic transmissions and/or continuously variable transmissions.

[Background Art]

Up to now, automatic transmissions have been required to have thermal oxidation stability, anti-wear properties, and friction characteristics for wet clutches. In order to enhance such properties and characteristics, lubricants have been used which contain a base oil suitably blended with various additives such as anti-oxidants, detergent dispersants, anti-wear agents, friction modifiers, seal swelling agents, viscosity index improvers, antifoamers, dyes, and the like.

Recent automatic transmissions are desired to be light in weight and compact in size and demanded to be enhanced in power transmission capability, resulting from the increased output of engines to be combined.

Lubricants used in such automatic transmissions are now demanded to possess properties capable of preventing pitching (defects occurring when lubricated surfaces are damaged) on surfaces of bearings and gears so as to prolong the fatigue life thereof while maintaining high lubricating performance properties.

In recent years, a control, so-called "slip lock-up control" wherein the lock-up clutch equipped in a torque converter is given a small degree of slip in a low speed range is employed in many of automatic transmissions. The slip lock-up control can transmit engine torque to a transmission mechanism efficiently while improving the riding comfort by absorbing the torque fluctuation. Some of continuously variable transmissions employ a so-called "slip control" for effecting a smooth start from the stop state by slipping and then engaging the wet starting clutch. In this connection, lubricants are demanded to have excellent and long-lasting anti-shudder properties for the slip control of such lock-up clutches and starting clutches.

It is common knowledge that a lubricant containing sulfur-based additives providing excellent extreme pressure properties and anti-wear properties is effective in prolonging the fatigue life of bearings, gears or the like. However, since the sulfur-based additives are excellent in extreme pressure properties but can not avoid wears caused by corrosion and abrasion

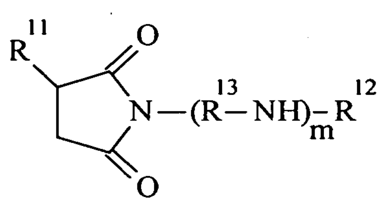
due to their strong activity to metal surfaces, the single use of such additives may arise a problem.

In order to obtain anti-shudder properties and prolong the duration thereof , it is necessary to add a suitable amount of a friction modifier capable of maintaining the friction characteristics of a lock-up clutch, to a lubricating oil. However, the friction modifier is less effective in prolonging fatigue life and will be decreased in anti-shudder maintaining effect at an early stage due to a deterioration in oxidation stability of the lubricating oil when the friction modifier is used in combination with the above-described sulfur-based additive. That is, it has been found difficult to achieve anti-pitching properties and excellent and long-lasting anti-shudder properties with conventional lubricating oils at the same time.

In view of the foregoing situations, the object of the present invention is to provide a lubricating oil composition having both anti-pitching properties capable of providing a transmission with long fatigue life and sufficient and long-lasting anti-shudder properties, particularly suitable for automatic transmissions and/or continuously variable transmission.

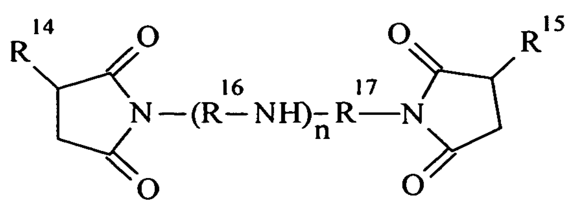
[Disclosures of the Invention]

According to the present invention, there is provided a lubricating oil composition which comprises (A) a base oil, (B) calcium salicylate having a base number of 50 to 300 mgKOH/g in an amount of 0.005 to 0.07 percent by mass in terms of calcium, (C) an SP type extreme pressure additive in an amount of 0.005 to 0.07 percent by mass in terms of phosphorous, (D) one or more compounds selected from the group consisting of succinimide compounds represented by formulas (3) and (4) below in an amount of 0.1 to 6 percent by mass, and (E) a boron-containing ashless dispersant in an amount of 0.001 to 0.05 percent by mass in terms of boron, based on the total mass of the composition:



(3)

wherein R^{11} is a straight-chain or branched hydrocarbon group having 8 to 30 carbon atoms, R^{12} is hydrogen or a hydrocarbon group having 1 to 30 carbon atoms, R^{13} is a hydrocarbon group having 1 to 4 carbon atoms, and m is an integer of from 1 to 7;



(4)

wherein R^{14} and R^{15} are each independently a straight-chain or branched hydrocarbon group having 8 to 30 carbon atoms, and R^{16} and R^{17} are each independently a hydrocarbon group having 1 to 4 carbon atoms, and n is an integer of from 1 to 7.

The present invention will be described in more details below.

Lubricating base oils (A) used in the present invention may be any mineral oils and/or synthetic oils which have conventionally been used as base oils for lubricating oils.

Examples of such mineral base oil include paraffinic or naphthenic oils which can be obtained by subjecting a lubricating oil fraction produced by atmospheric- or vacuum-distilling a crude oil, to any one or more refining processes selected from solvent deasphalting, solvent extraction, hydrocracking, solvent dewaxing, catalytic dewaxing, hydrorefining, washing with sulfuric acid, and clay treatment; and n-paraffines.

Examples of synthetic base oils include poly-α-olefins such as 1-octene oligomer, 1-decene oligomer, and ethylene-propylene oligomer, and hydrides thereof; isobutene oligomer and hydrides thereof; isoparaffines; alkylbenzenes; alkylnaphthalenes; diesters such as ditridecyl glutarate, di-2-ethylhexyl

adipate, diisodecyl adipate, ditridecyl adipate, and di-2-ethylhexyl cebacate; polyol esters such as trimethylolpropane caprylate, trimethylolpropane pelargonate, pentaerythritol-2-ethyl hexanoate, and pentaerythritol pelargonate; polyoxyalkylene glycols; dialkyldiphenyl ethers; and polyphenyl ethers.

In order to further improve fatigue life, it is preferred to use a mixture of two types of base oils having a different kinematic viscosity, i.e., a mixture of (A-1) a mineral or synthetic oil having a kinematic viscosity at 100 ℃ of 2 to 6 mm^2/s, or a mixture thereof and (A-2) a heavy mineral oil having a kinematic viscosity at 100 ℃ of 10 to 50 mm^2/s, preferably 15 to 45 mm^2/s. A base oil obtained by mixing (A-1) and (A-2) oils has a kinematic viscosity at 100 ℃ of 1 to 10 mm^2/s, preferably 2 to 8 mm^2/s.

The mix ratio of a base oil with a kinematic viscosity of (A-1) to a base oil with a kinematic viscosity of (A-2) is preferably 60 to 99.5 : 40 to 0.5 by mass, more preferably 65 to 95 : 35 to 5. A base oil of a kinematic viscosity of (A-2) in an amount of less than 0.5 percent by mass would fail to obtain a further improvement in fatigue life caused by addition of the heavy base oil, while a base oil of a kinematic viscosity of (A-2) in an amount of more than 40 percent by mass would deteriorate the low-temperature fluidity of the resulting lubricating oil and thus would

adversely affect the low-temperature startability of a transmission.

Examples of Component (B), i.e., calcium salicylate include neutral calcium salicylates, basic calcium salicylates, carbonated overbased calcium salicylates, borated overbased calcium salicylates, and mixtures thereof.

No particular limitation is imposed on a method of producing calcium salicylate. For example, a neutral calcium salicylate mentioned above may be produced by reacting an alkyl salicylic acid having one or two alkyl groups having 10 to 30, preferably 12 to 20, and more preferably 14 to 18 carbon atoms with a calcium base such as an oxide or hydroxide of calcium, in the presence or absence of sulfur. Examples of the alkyl group of the alkyl salicylic acid include decyl, undecyl, dodecyl, tridecyl, tetradecyl, pentadecyl, hexadecyl, heptadecyl, octadecyl, nonadecyl, eicosyl, heneicosyl, docosyl, tricosyl, tetracosyl, pentacosyl, hexacosyl, heptacosyl, octacosyl, nonacosyl, and triacontyl groups. Among these alkyl groups, preferred are tetradecyl, pentadecyl, hexadecyl, heptadecyl, and octadecyl groups. A basic calcium salicylate as mentioned above may be produced by heating a neutral calcium salicylate as mentioned above and a calcium salt or base in an excess amount in the

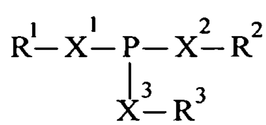
presence of water. A carbonated overbased calcium salicylate as mentioned above may be produced by reacting a neutral calcium salicylate as mentioned above with a calcium base in the presence of carbon dioxide gas. A borated overbased calcium salicylate may be produced by reacting a neutral calcium salicylate as mentioned above with a calcium base and a boric acid compound such as boric acid or anhydrous boric acid or reacting a carbonated overbased calcium salicylate as mentioned above with a boric acid compound such as boric acid or anhydrous boric acid.

Component (B) is preferably a basic calcium salicylate having a base number of 50 to 300 mgKOH/g, preferably 70 to 250 mgKOH/g. The term "base number" used herein denotes a base number measured by the perchloric acid potentiometric titration method in accordance with section 7 of JIS K2501 (1992) "Petroleum products and lubricants-Determination of neutralization number". Component (B) of a base number of less than 50 mgKOH/g would be less effective in suppressing a wet clutch from being decreased in strength against repeating compression applied thereto, while Component (B) of a base number of more than 300 mgKOH/g would deteriorate the storage stability of the resulting oil composition.

The lower limit content of Component (B) is 0.005 percent by mass, preferably 0.01 percent by mass while

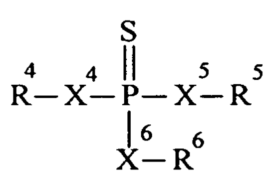
the upper limit content of Component (B) is 0.07 percent by mass, preferably 0.06 percent by mass. Component (B) of less than 0.005 percent by mass would be less effective in friction modifying capability and shortened the duration of anti-shudder properties. Component (B) of more than 0.07 percent by mass would cause a possibility that calcium salts formed upon decomposition of Component (B), i.e., calcium salicylate clog the hollow hole of a wet friction clutch and thus change the friction coefficient.

Component (C) of the lubricating oil composition of the present invention is an SP type extreme pressure additive. More specifically, examples of Component (C) are phosphorus compounds represented by formulas (1) and (2) and salts thereof:



(1)

wherein at least one of X^1, X^2, and X^3 is sulfur and the remainder is oxygen, and R^1, R^2, and R^3 are each independently hydrogen or a hydrocarbon group having 1 to 30 carbon atoms; and



(2)

wherein X^4, X^5, and X^6 are each independently oxygen or sulfur, and R^4, R^5, and R^6 are each independently hydrogen or a hydrocarbon having 1 to 30 carbon atoms.

Specific examples of hydrocarbons having 1 to 30 carbon atoms for R^1 to R^6 include alkyl, cycloalkyl, alkenyl, alkyl-substituted cycloalkyl, aryl, alkyl-substituted aryl, and arylalkyl groups.

Examples of the alkyl group include straight-chain or branched alkyl groups such as methyl, ethyl, propyl, butyl, pentyl, hexyl, heptyl, octyl, nonyl, decyl, undecyl, dodecyl, tridecyl, tetradecyl, pentadecyl, hexadecyl, heptadecyl, and octadecyl groups.

Examples of the cycloalkyl group include those having 5 to 7 carbon atoms, such as cyclopentyl, cyclohexyl, and cycloheptyl groups. Examples of the alkylcycloalkyl groups include those having 6 to 11 carbon atoms, such as methylcyclopentyl, dimethylcyclopentyl, methylethylcyclopentyl, diethylcyclopentyl, methylcyclohexyl, dimethylcyclohexyl, methylethylcyclohexyl, diethylcyclohexyl, methylcycloheptyl, dimethylcycloheptyl, methylethylcycloheptyl, and diethylcycloheptyl groups, of which the alkyl groups may bond to any position of the cycloalkyl groups.

Examples of the alkenyl group include butenyl, pentenyl, hexenyl, heptenyl, octenyl, noneyl, decenyl,

undecenyl, dodecenyl, tridecenyl, tetradecenyl, pentadecenyl, hexadecenyl, heptadecenyl, and octadecenyl groups, all of which may be straight-chain or branched and the position of which the double bonds may vary.

Examples of the aryl group include phenyl and naphtyl groups. Examples of the alkylaryl group include those having 7 to 18 carbon atoms, such as tolyl, xylyl, ethylphenyl, propylphenyl, butylphenyl, pentylphenyl, hexylphenyl, heptylphenyl, octylphenyl, nonylphenyl, decylphenyl, undecylphenyl, and dodecylphenyl groups, of which the alkyl groups may be straight-chain or branched and may bond to any position of the aryl groups.

Examples of the arylalkyl groups include those having 7 to 12 carbon atoms, such as benzyl, phenylethyl, phenylpropyl, phenylbutyl, phenylpentyl, and phenylhexyl groups, of which the alkyl groups may be straight-chain or branched.

Hydrocarbon groups having 1 to 30 carbon atoms for R^1 to R^6 are preferably alkyl groups having 1 to 30 carbon atoms and aryl groups having 6 to 24 carbon atoms, more preferably alkyl groups having 4 to 20 carbon atoms, and further more preferably alkyl groups having 6 to 18 carbon atoms.

Examples of SP type extreme pressure additives represented by formula (1) include the following

phosphorus compounds:

thiophosphite;

monoalkylthiophosphites of which the alkyl group may be straight-chain or branched, such as monopropylthiophosphite, monobutylthiophosphite, monopentylthiophosphite, monohexylthiophosphite, monoheptylthiophosphite, monooctylthiophosphite, and monolaurylthiophosphite;

mono((alkyl)aryl)thiophosphites, such as monophenylthiophosphite and monocresylthiophosphite;

dialkylthiophosphites of which the alkyl groups may be straight-chain or branched, such as dipropylthiophosphite, dibutylthiophosphite, dipentylthiophosphite, dihexylthiophosphite, diheptylthiophosphite, dioctylthiophosphite, and dilaurylthiophosphite; di((alkyl)aryl)thiophosphite such as diphenylthiophosphite and dicresylthiophosphite; trialkylthiophosphites of which the alkyl groups may be straight-chain or branched, such as tripropylthiophosphite, tributylthiophosphite, tripentylthiophosphite, trihexylthiophosphite, triheptylthiophosphite, trioctylthiophosphite, and trilaurylthiophosphite; tri((alkyl)aryl)thiophosphites such as triphenylthiophosphite and tircresylthiophosphite;

dithiophosphite;

monoalkyldithiophosphites of which the alkyl groups

may be straight-chain or branched, such as monopropyldithiophosphite, monobutyldithiophosphite, monopentyldithiophosphite, monohexyldithiophosphite, monoheptyldithiophosphite, monooctyldithiophosphite, and monolauryldithiophosphite;
mono((alkyl)aryl)dithiophosphites, such as monophenyldithiophosphite and monocresyldithiophosphite; dialkyldithiophosphites of which the alkyl groups may be straight-chain or branched, such as dipropyldithiophosphite, dibutyldithiophosphite, dipentyldithiophosphite, dihexyldithiophosphite, diheptyldithiophosphite, dioctyldithiophosphite, and dilauryldithiophosphite;
di((alkyl)aryl)dithiophosphite such as diphenyldithiophosphite and dicresyldithiophosphite;
trialkyldithiophosphites of which the alkyl groups may be straight-chain or branched, such as tripropyldithiophosphite, tributyldithiophosphite, tripentyldithiophosphite, trihexyldithiophosphite, triheptyldithiophosphite, trioctyldithiophosphite, and trilauryldithiophosphite;
tri((alkyl)aryl)dithiophosphites such as triphenyldithiophosphite and tircresyldithiophosphite;
trithiophosphite;
monoalkyltrithiophosphites of which the alkyl groups may be straight-chain or branched, such as

monopropyltrithiophosphite, monobutyltrithiophosphite, monopentyltrithiophosphite, monohexyltrithiophosphite, monoheptyltrithiophosphite, monooctyltrithiophosphite, and monolauryltrithiophosphite; mono((alkyl)aryl)trithiophosphites, such as monophenyltrithiophosphite and monocresyltrithiophosphite; dialkyltrithiophosphites of which the alkyl groups may be straight-chain or branched, such as dipropyltrithiophosphite, dibutyltrithiophosphite, dipentyltrithiophosphite, dihexyltrithiophosphite, diheptyltrithiophosphite, dioctyltrithiophosphite, and dilauryltrithiophosphite; di((alkyl)aryl)trithiophosphite such as diphenyltrithiophosphite and dicresyltrithiophosphite; trialkyltrithiophosphites of which the alkyl groups may be straight-chain or branched, such as tripropyltrithiophosphite, tributyltrithiophosphite, tripentyltrithiophosphite, trihexyltrithiophosphite, triheptyltrithiophosphite, trioctyltrithiophosphite, and trilauryltrithiophosphite; tri((alkyl)aryl)trithiophosphites such as triphenyltrithiophosphite and

tircresyltrithiophosphite; and mixtures thereof.

In the present invention, preferably two or more of X^1 to X^3 are sulfur, and more preferably all of X^1 to X^3 are sulfur.

Examples of SP type extreme pressure additives represented by formula (2) include the following phosphorus compounds:
thiophosphate;
monoalkylthiophosphates of which the alkyl groups may be straight-chain or branched, such as monopropylthiophosphate, monobutylthiophosphate; monopentylthiophosphate, monohexylthiophosphate, monoheptylthiophosphate, monooctylthiophosphate, and monolaurylthiophosphate;
mono((alkyl)aryl)thiophosphates, such as monophenylthiophosphate and monocresylthiophosphate; dialkylthiophosphates of which the alkyl groups may be straight-chain or branched, such as dipropylthiophosphate, dibutylthiophosphate, dipentylthiophosphate, dihexylthiophosphate, diheptylthiophosphate, dioctylthiophosphate, and dilaurylthiophosphate; di((alkyl)aryl)thiophosphate such as diphenylthiophosphate and dicresylthiophosphate; trialkylthiophosphates of which the alkyl groups may be straight-chain or branched, such as tripropylthiophosphate, tributylthiophosphate, tripentylthiophosphate,

trihexylthiophosphate, triheptylthiophosphate, trioctylthiophosphate, and trilaurylthiophosphate; tri((alkyl)aryl)thiophosphates such as triphenylthiophosphate and tircresylthiophosphate; dithiophosphate; monoalkyldithiophosphates of which the alkyl group may be straight-chain or branched, such as monopropyldithiophosphate, monobutyldithiophosphate; monopentyldithiophosphate, monohexyldithiophosphate, monoheptyldithiophosphate, monooctyldithiophosphate, and monolauryldithiophosphate; mono((alkyl)aryl)dithiophosphates, such as monophenyldithiophosphate and monocresyldithiophosphate; dialkyldithiophosphates of which the alkyl groups may be straight-chain or branched, such as dipropyldithiophosphate, dibutyldithiophosphate, dipentyldithiophosphate, dihexyldithiophosphate, diheptyldithiophosphate, dioctyldithiophosphate, and dilauryldithiophosphate; di((alkyl)aryl)dithiophosphates such as diphenyldithiophosphate and dicresyldithiophosphate; trialkyldithiophosphates of which the alkyl groups may be straight-chain or branched, such as tripropyldithiophosphate, tributyldithiophosphate, tripentyldithiophosphate, trihexyldithiophosphate, triheptyldithiophosphate, trioctyldithiophosphate,

and trilauryldithiophosphate;
tri((alkyl)aryl)dithiophosphates such as triphenyldithiophosphate and tircresyldithiophosphate;
trithiophosphate;
monoalkyltrithiophosphates of which the alkyl groups may be straight-chain or branched, such as monopropyltrithiophosphate, monobutyltrithiophosphate; monopentyltrithiophosphate, monohexyltrithiophosphate, monoheptyltrithiophosphate, monooctyltrithiophosphate, and monolauryltrithiophosphate;
mono((alkyl)aryl)trithiophosphates, such as monophenyltrithiophosphate and monocresyltrithiophosphate;
dialkyltrithiophosphates of which the alkyl groups may be straight-chain or branched, such as dipropyltrithiophosphate, dibutyltrithiophosphate, dipentyltrithiophosphate, dihexyltrithiophosphate, diheptyltrithiophosphate, dioctyltrithiophosphate, and dilauryltrithiophosphate;
di((alkyl)aryl)trithiophosphates such as diphenyltrithiophosphate and dicresyltrithiophosphate; trialkyltrithiophosphates of which the alkyl groups may be straight-chain or

branched, such as tripropyltrithiophosphate, tributyltrithiophosphate, tripentyltrithiophosphate, trihexyltrithiophosphate, triheptyltrithiophosphate, trioctyltrithiophosphate, and trilauryltrithiophosphate;

tri((alkyl)aryl)trithiophosphates such as triphenyltrithiophosphate and tircresyltrithiophosphate;

tetrathiophosphate;

monoalkyltetrathiophosphates of which the alkyl groups may be straight-chain or branched, such as monopropyltetrathiophosphate, monobutyltetrathiophosphate; monopentyltetrathiophosphate, monohexyltetrathiophosphate, monoheptyltetrathiophosphate, monooctyltetrathiophosphate, and monolauryltetrathiophosphate;

mono((alkyl)aryl)tetrathiophosphates, such as monophenyltetrathiophosphate and monocresyltetrathiophosphate;

dialkyltetrathiophosphates of which the alkyl groups may be straight-chain or branched, such as dipropyltetrathiophosphate, dibutyltetrathiophosphate, dipentyltetrathiophosphate, dihexyltetrathiophosphate,

diheptyltetrathiophosphate,
dioctyltetrathiophosphate, and
dilauryltetrathiophosphate;
di((alkyl)aryl)tetrathiophosphates such as
diphenyltetrathiophosphate and
dicresyltetrathiophosphate;
trialkyltetrathiophosphates of which the alkyl groups may be straight-chain or branched, such as
tripropyltetrathiophosphate,
tributyltetrathiophosphate,
tripentyltetrathiophosphate,
trihexyltetrathiophosphate,
triheptyltetrathiophosphate,
trioctyltetrathiophosphate, and
trilauryltetrathiophosphate;
tri((alkyl)aryl)tetrathiophosphates such as
triphenyltetrathiophosphate and
tircresyltetrathiophosphate; and mixtures thereof.

In the present invention, preferably one to three of X^4 to X^6 are sulfur, and more preferably one or two of X^4 to X^6 are sulfur.

Examples of salts of phosphorus compounds represented by formula (1) or (2) are those obtained by allowing a phosphorus compound to react with a nitrogen-containing compound such as ammonia or an amine compound having in its molecules only hydrocarbon or hydroxyl-containing hydrocarbon groups having 1 to

8 carbon atoms so as to neutralize the whole or part of the remaining acid hydrogen.

Specific examples of the nitrogen-containing compound are ammonia; alkylamines, of which the alkyl groups may be straight-chain or branched, such as monomethylamine, monoethylamine, monopropylamine, monobutylamine, monopentylamine, monohexylamine, monoheptylamine, monooctylamine, dimethylamine, methylethylamine, diethylamine, methylpropylamine, ethylpropylamine, dipropylamine, methylbutylamine, ethylbutylamine, propylbutylamine, dibutylamine, dipentylamine, dihexylamine, diheptylamine and dioctylamine; alkanolamines, of which the alkanol groups may be straight-chain or branched, such as monomethanolamine, monoethanolamine, monopropanolamine, monobutanolamine, monopentanolamine, monohexanolamine, monoheptanolamine, monooctanolamine, monononanolamine, dimethanolamine, methanolethanolamine, diethanolamine, methanolpropanolamine, ethanolpropanolamine, dipropanolamine, methanolbutanolamine, ethanolbutanolamine, propanolbutanolamine, dibutanolamine, dipentanolamine, dihexanolamine, diheptanolamine and dioctanolamine; and mixtures thereof.

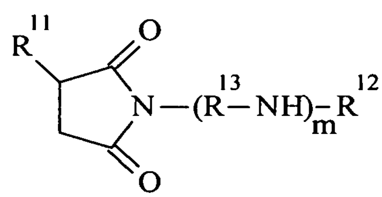
One or more of these Components (C) may be blended

arbitrarily.

The use of Component (C) makes it possible to provide not only anti-wear properties but also optimized friction characteristics for a wet clutch.

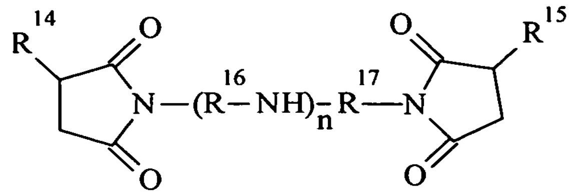
The lubricating oil composition of the present invention contains Component (C) in an amount of 0.005 percent by mass or more, preferably 0.008 percent by mass or more and 0.07 percent by mass or less, preferably 0.06 percent by mass or less, in terms of phosphorus based on the total mass of the composition. Component (C) of less than 0.005 percent would be ineffective in anti-wear properties, while Component (C) in excess of 0.07 percent by mass would be prone to cause pitching.

Component (D) of the lubricating oil composition of the present invention is a succinimide compound represented by formula (3) or (4) below:



(3)

wherein R^{11} is a straight-chain or branched hydrocarbon having 8 to 30 carbon atoms, R^{12} is hydrogen or a hydrocarbon group having 1 to 30 carbon atoms, R^{13} is a hydrocarbon group having 1 to 4 carbon atoms, and m is an integer of from 1 to 7; and



(4)

wherein R^{14} and R^{15} are each independently a straight-chain or branched hydrocarbon group having 8 to 30 carbon atoms, R^{16} and R^{17} are each independently a hydrocarbon group having 1 to 4 carbon atoms, and n is an integer of from 1 to 7.

R^{11} in formula (3) and R^{14} and R^{15} in formula (4) are each independently a straight-chain or branched hydrocarbon group having 8 to 30, preferably 12 to 25 carbon atoms. Examples of such a hydrocarbon group are include alkyl and alkenyl groups. Preferred are alkyl groups. Examples of the alkyl groups are octyl, octenyl, nonyl, nonenyl, decyl, decenyl, dodecyl, dodecenyl, octadecyl, octadecenyl, and straight-chain or branched alkyl groups having up to 30 carbon atoms. A hydrocarbon group having fewer than 8 carbon atoms or more than 30 carbon atoms would be ineffective in anti-shudder vibration. Preferred are branched alkyl groups having 8 to 30 carbon atoms, and particularly preferred are branched alkyl groups having 10 to 25 carbon atoms. A branched alkyl group having 8 to 30 carbon atoms results in a lubricating oil composition exhibiting a higher torque capacity than a straight-chain alkyl group.

R^{13} in formula (3) and R^{16} and R^{17} in formula (4) are each independently a hydrocarbon group having 1 to 4 carbon atoms. Examples of such a hydrocarbon include alkylene groups having 1 to 4 carbon atoms, preferably alkylene groups having 2 or 3 carbon atoms (ethylene, propylene).

R^{12} in formula (3) is hydrogen or a straight-chain or branched hydrocarbon group having 1 to 30 carbon atoms. Examples of such a straight-chain or branched hydrocarbon group include straight-chain or branched alkyl or alkenyl groups having 1 to 30 carbon atoms. Preferred are branched alkyl or alkenyl groups having 1 to 30 carbon atoms, more preferred are branched alkyl or alkenyl groups having 8 to 30 carbon atoms, and further more preferred are branched alkyl or alkenyl groups having 10 to 25 carbon atoms. Particularly preferred are branched alkyl groups.

In formulas (3) and (4), m and n are each independently an integer of from 1 to 7. In order to obtain a lubricating oil composition exhibiting a higher torque capacity, m and n are each independently preferably 1, 2, or 3, particularly preferably 1.

A succinimide compound represented by formula (3) or (4) may be produced by a conventional method. For example, such a succinimide compound may be produced by reacting an alkyl or alkenyl succinic anhydride with a polyamine. More specifically, a monosuccinimide of

formula (3) wherein R^{12} is hydrogen may be obtained by adding dropwise 1 mole of a succinic anhydride having a straight-chain or branched alkyl or alkenyl group having 8 to 30 carbon atoms to 1 mole or more of a polyamine such as diethylenetriamine, triethylenetetramine, and tetraethylenepentamine under a nitrogen atmosphere at a temperature of 130 to 180 ℃, preferably 140 to 175 ℃ for 1 to 10 hours, preferably 2 to 6 hours and by distilling out the unreacted polyamine. A monosuccinimide of formula (3) wherein R^{12} is a hydrocarbon group having 1 to 30 carbon atoms may be obtained by reacting N-octadecyl-1,3-propanediamine with succinic anhydride as described above by the same method as described above. A bis succinimide represented by formula (4) may be obtained by reacting 0.5 mol of a polyamine as mentioned above with 1 mol of succinic anhydride as described above under the same reaction conditions as described above and removing the water generated.

In the present invention, Component (D) is preferably a bis-type succinimide represented by formula (4) because the use of a bis-type succinimide is contributive to the production of a lubricating oil composition with a higher torque transmission capacity, compared with a mono-type succinimide represented by formula (3).

The content of Component (D) in the lubricating oil composition of the present invention is 0.1 percent by mass or more, preferably 0.2 percent by mass or more, based on the total mass of the composition. The content of Component (D) is 6 percent by mass or less, preferably 4 percent by mass or less, based on the total mass of the composition. Component (D) of less than 0.1 percent by mass would be ineffective in maintaining excellent anti-shudder properties and shifting properties, while Component (D) in excess of 6 percent by mass would fail to attain effects as expected.

Component (E) of the lubricating oil composition of the present invention is a boron-containing ashless dispersant. Component (E) importantly contains boron. In the case where a boron-free ashless dispersant is used as Component (E), it can not achieve the purposes of the present invention because it not only fails to inhibit fatigue caused by pitching or flaking and provide anti-shudder properties but also becomes ineffective in anti-wear properties and oxidation stability as a lubricating oil composition even though it is used in combination with Components (B) and (C).

Specific examples of Component (E) include modified products obtained by modifying a nitrogen-containing compounds or derivative thereof, having at least one alkyl or alkenyl group having 40

to 400 carbon atoms in the molecules, with a boron compound. Any one or more kinds selected from these compounds may be blended.

The alkyl or alkenyl group may be straight-chain or branched but is preferably a branched alkyl or alkenyl group derived from an oligomer of an olefin such as propylene, 1-butene, and isobutylene or a cooligomer of ethylene and propylene.

Although the carbon number of the alkyl or alkenyl group is optional, it is preferably 40 to 400, more preferably 60 to 350 carbon atoms. An alkyl or alkenyl group having fewer than 40 carbon atoms would deteriorate the solubility of the compound in a base oil, while an alkyl or alkenyl group having more than 400 carbon atoms would deteriorate the low-temperature fluidity of the resulting lubricating oil composition.

Specific examples of the above-mentioned nitrogen-containing compound or derivative include any one or more kinds of compounds selected from:

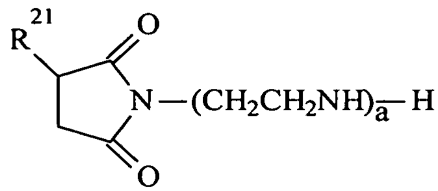
(E-1) succinimides having at least one alkyl or alkenyl group having 40 to 400 carbon atoms in the molecules or derivatives thereof;

(E-2) benzylamines having at least one alkyl or alkenyl group having 40 to 400 carbon atoms in the molecules or derivatives thereof; and

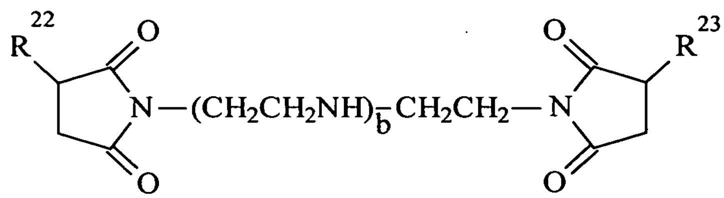
(E-3) polyamines having at least one alkyl or alkenyl group having 40 to 400 carbon atoms in the

molecules or derivatives thereof.

Specific examples of (E-1) succinimides are those represented by the following formulas:



(5)



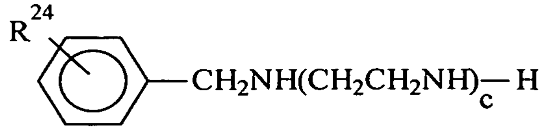
(6)

In formula (5), R^{21} is an alkyl or alkenyl group having 40 to 400, preferably 60 to 350 carbon atoms, and a is an integer of from 1 to 5, preferably 2 to 4.

In formula (6), R^{22} and R^{23} are each independently an alkyl or alkenyl group having 40 to 400, preferably 60 to 350 carbon atoms, and b is an integer of from 0 to 4, preferably 1 to 3.

Mono-type succinimides represented by formula (5) and bis-type succinimides represented by formula (6) may be used singlely or in combination.

Specific examples of (E-2) benzylamines are compounds represented by the formula



(7)

In formula (7), R^{24} is an alkyl or alkenyl group having 40 to 400, preferably 60 to 350 carbon atoms, and c is an integer of from 1 to 5, preferably 2 to 4.

No particular limitation is imposed on the method of producing the benzylamines. However, for example, one of the benzylamines may be produced by reacting a polyolefin such as propylene oligomer, polybutene, or an ethylene-α-olefin copolymer with a phenol so as to obtain an alkylphenol, followed by a Mannich reaction thereof with formaldehyde and a polyamine such as diethylenetriamine, triethylenetetramine, tetraethylenepentamine, or pentaethylenehexamine.

Specific examples of (E-3) polyamines are compounds represented by the formula

$$R^{25}-NH-(CH_2CH_2NH)_d-H \qquad (8)$$

In formula (8), R^{25} is an alkyl or alkenyl group having 40 to 400, preferably 60 to 350 carbon atoms, and d is an integer of from 1 to 5, preferably 2 to 4.

No particular limitation is imposed on the method of producing the polyamines represented by formula (8). For example, one of the polyamines may be produced by subjecting a polyolefin such as propylene oligomer, polybutene, or an ethylene-α-olefin copolymer to chloridization, followed by a reaction thereof with ammonia or a polyamine such as ethylenediamine, diethylenetriamine, triethylenetetramine,

tetraethylenepentamine, or pentaethylenehexamine.

Specific examples of the derivatives of the nitrogen compounds (E-1) to (E-3) are carboxylic acid-modified compounds obtained by allowing any one of the aforesaid nitrogen compounds to react with a monocarboxylic acid (fatty acid) having 2 to 30 carbon atoms or a polycarboxylic acid having 2 to 30 carbon atoms, such as oxalic acid, phthalic acid, trimellitic acid, or pyromellitic acid so as to neutralize or amidize the whole or part of the remaining amino and/or imino groups; sulfur-modified compounds obtained by allowing any one of the aforesaid nitrogen compounds to react with a sulfuric compound; and mixtures thereof.

Component (E) used in the present invention is a compound obtained by modifying any one of the aforesaid nitrogen-containing compounds or a derivative thereof with a boron compound.

No particular limitation is imposed on the method of modifying the nitrogen compounds or derivatives thereof with a boron compound. Therefore, any suitable method may be employed. For example, any one of the aforesaid nitrogen compounds or derivatives thereof is reacted with a boron compound such as boric acid, a borate, or a boric acid ester so as to neutralize or amidize the whole or part of the amino and/or imino groups remaining in the nitrogen compound or derivative

thereof.

Specific examples of the boron compounds used herein include orthoboric acid, methaboric acid, and tetraboric acid. Examples of borates include alkali metal salts, alkaline earth metal salts, or ammonium salts of boric acid. More specific examples include lithium borate such as lithium methaborate, lithium tetraborate, lithium pentaborate, and lithium perborate; sodium borate such as sodium methaborate, sodium diborate, sodium tetraborate, sodium pentaborate, sodium hexaborate, and sodium octaborate; potassium borate such as potassium methaborate, potassium tetraborate, potassium pentaborate, potassium hexaborate, and potassium octaborate; calcium borate such as calcium methaborate, calcium diborate, tricalcium tetraborate, pentacalcium tetraborate, and calcium hexaborate; magnesium borate such as magnesium methaborate, magnesium diborate, trimagnesium tetraborate, pentamagnesium tetraborate, and magnesium hexaborate; and ammonium borate such as ammonium methaborate, ammonium tetraborate, ammonium pentaborate, and ammonium octaborate. Examples of the boric acid esters include esters of boric acid and an alkyl alcohol having 1 to 6 carbon atoms and more specifically monomethyl borate, dimethyl borate, trimethyl borate, monoethyl borate, diethyl borate, triethyl borate, monopropyl borate, dipropyl borate,

tripropyl borate, monobutyl borate, dibutyl borate, and tributyl borate.

No particular limitation is imposed on the boron content in Component (E). However, the boron content is preferably 0.2 percent by mass or more, more preferably 0.4 percent by mass or more and preferably 4 percent by mass or less, more preferably 2.5 percent by mass or less in order to obtain long fatigue life and excellent anti-wear properties.

Preferred for Component (E) are those obtained by modifying (E-1) succinimides having at least one alkyl or alkenyl group having 40 to 400 carbon atoms per molecule or derivatives thereof used as the aforesaid nitrogen-containing compounds with the aforesaid boron compounds; and mixtures thereof with the objective of improved fatigue life and anti-wear properties.

The content of Component (E) in the lubricating oil composition of the present invention is 0.001 percent by mass or more, preferably 0.002 percent by mass or more in terms of boron, based on the total mass of the composition and 0.05 percent by mass or less, preferably 0.03 percent by mass or less in terms of boron, based on the total mass of the composition. Component (E) of less than 0.001 percent would be ineffective in preventing pitching or flaking, while Component (E) of more than 0.05 percent by mass would deteriorate the oxidation stability of the resulting composition.

The lubricating oil composition of the present invention may be blended with known additives for the purpose of further enhancing its functions as a lubricating oil. Examples of such additives include (F) phosphorus extreme pressure additives, (G) boron-free ashless dispersants, (H) metal detergents other than Component (B), (I) friction modifiers, (J) anti-oxidants, (K) viscosity index improvers, (L) antifoamers, (M) rust preventives, (N) corrosion inhibitors, (O) pour-point depressants, and (P) rubber swelling agents. These additives may be used singlely or in combination.

Addition of Component (F), i.e., phosphorus extreme pressure additives to the lubricating oil composition of the present invention is preferable because it can favorably maintain anti-wear properties for gears and friction characteristics for wet clutches.

Examples of the phosphorus extreme pressure additives include zinc alkyldithiophosphates, phosphoric acid, phosphorous acid, monophosphates, diphosphates, triphosphates, monophosphites, diphosphites, triphosphites, salts of phosphates and phosphites, and mixtures thereof.

Among these phosphorus extreme pressure additives,

those other than phosphoric acid and phosphorus acid are compounds containing a hydrocarbon group having 2 to 30, preferably 3 to 20 carbon atoms.

Examples of hydrocarbon groups having 2 to 30 carbon atoms include alkyl groups such as ethyl, propyl, butyl, pentyl, hexyl, heptyl, octyl, nonyl, decyl, undecyl, dodecyl, tridecyl, tetradecyl, pentadecyl, hexadecyl, heptadecyl, and octadecyl groups, all of which may be straight-chain or branched; alkenyl groups such as butenyl, pentenyl, hexenyl, heptenyl, octenyl, nonenyl, decenyl, undecenyl, dodecenyl, tridecenyl, tetradecenyl, pentadecenyl, hexadecenyl, heptadecenyl and octadecenyl groups, all of which may be straight-chain or branched and the position of which the double bonds may vary; cycloalkyl groups having 5 to 7 carbon atoms, such as cyclopentyl, cyclohexyl, and cycloheptyl groups; alkylcycloalkyl groups having 6 to 11 carbon atoms, such as methylcyclopentyl, dimethylcyclopentyl, methylethylcyclopentyl, diethylcyclopentyl, methylcyclohexyl, dimethylcyclohexyl, methylethylcyclohexyl, diethylcyclohexyl, methylcycloheptyl, dimethylcycloheptyl, methylethylcycloheptyl and diethylcycloheptyl groups, of which the cycloalkyl groups may possess an alkyl substituent at any position; aryl groups such as phenyl and naphthyl; alkylaryl groups having 7 to 18 carbon atoms, such as

tolyl, xylyl, ethylphenyl, propylphenyl, butylphenyl, pentylphenyl, hexylphenyl, heptylphenyl, octylphenyl, nonylphenyl, decylphenyl, undecylphenyl, and dodecylphenyl groups, all of which the alkyl groups may be straight-chain or branched and may bond to any position of the aryl group; and arylalkyl groups having 7 to 12 carbon atoms, such as benzyl, phenylethyl, phenylpropyl, phenylbutyl, phenylpentyl and phenylhexyl groups, all of which alkyl groups may be straight-chain or branched.

Preferred compounds as Component (F) are phosphoric acid; phosphorus acid; zinc alkyldithiophosphates, of which the alkyl groups may be straight-chain or branched, such as zinc dipropyldithiophosphate, zinc dibutyldithiophosphate, zinc dipentyldithiophosphate, zinc dihexyldithiophosphate, zinc diheptyldithiophosphate, and zinc dioctyldithiophosphate; monoalkyl phosphates, of which the alkyl groups may be straight-chain or branched, such as monopropyl phosphate, monobutyl phosphate, monopentyl phosphate, monohexyl phosphate, monoheptyl phosphate, and monooctyl phosphate; mono(alkyl)aryl phosphates such as monophenyl phosphate and monocresyl phosphate; dialkyl phosphates, of which the alkyl groups may be straight-chain or branched, such as dipropyl phosphate, dibutyl phosphate, dipentyl phosphate, dihexyl phosphate,

diheptyl phosphate, and dioctyl phosphate; di(alkyl)aryl phosphates such as diphenyl phosphate and dicresyl phospahte; trialkyl phosphates, of which the alkyl groups may be straight-chain or branched, such as tripropyl phosphate, tributyl phosphate, tripentyl phosphate, trihexyl phosphate, triheptyl phosphate, and trioctyl phosphate; tri(alkyl)aryl phosphates such as triphenyl phosphate and tricresyl phosphate; monoalkyl phosphites, of which the alkyl groups may be straight-chain or branched, such as monopropyl phosphite, monobutyl phosphite, monopentyl phosphite, monohexyl phosphite, monoheptyl phosphite, and monooctyl phosphite; mono(alkyl)aryl phosphites such as monophenyl phosphite and monocresyl phosphite; dialkyl phosphites, of which the alkyl groups may be straight-chain or branched, such as dipropyl phosphite, dibutyl phosphite, dipentyl phosphite, dihexyl phosphite, diheptyl phosphite, and dioctyl phosphite; di(alkyl)aryl phosphites such as diphenyl phosphite and dicresyl phosphite; trialkyl phosphites, of which the alkyl groups may be straight-chain or branched, such as tripropyl phosphite, tributyl phosphite, tripentyl phosphite, trihexyl phosphite, triheptyl phosphite, and trioctyl phosphite; tri(alkyl)aryl phosphites, such as triphenyl phosphite and tricresyl phosphite; and mixtures thereof.

Specific examples of salts of phosphates and

phosphites include those obtained by allowing monophosphate, diphosphate, monophosphite, or diphosphite to react with a nitrogen compound such as ammonia or an amine compound having in its molecules only a hydrocarbon group or hydroxyl-containing hydrocarbon group having 1 to 8 carbon atoms so as to neutralize the whole or part of the remaining acid hydrogen.

Specific examples of the nitrogen compound include ammonia; alkylamines, of which the alkyl groups may be straight-chain or branched, such as monomethylamine, monoethylamine, monopropylamine, monobutylamine, monopentylamine, monohexylamine, monoheptylamine, monooctylamine, dimethylamine, methylethylamine, diethylamine, methylpropylamine, ethylpropylamine, dipropylamine, methylbutylamine, ethylbutylamine, propylbutylamine, dibutylamine, dipentylamine, dihexylamine, diheptylamine, and dioctylamine; alkanolamines, of which the alkanol groups may be straight-chain or branched, such as monomethanolamine, monoethanolamine, monopropanolamine, monobutanolamine, monopentanolamine, monohexanolamine, monoheptanolamine, monooctanolamine, monononanolamine, dimethanolamine, methanolethanolamine, diethanolamine, methanolpropanolamine, ethanolpropanolamine,

dipropanolamine, methanolbutanolamine, ethanolbutanolamine, propanolbutanolamine, dibutanolamine, dipentanolamine, dihexanolamine, diheptanolamine, and dioctanolamine; and mixtures thereof.

One or more Components (F) may be arbitrarily added to the lubricating oil composition of the present invention.

No particular limitation is imposed on the content of Component (F). However, the lubricating oil composition preferably contains Component (F) in an amount of 0.005 to 0.2 percent by mass in terms of phosphorus, based on the total mass of the composition. Component (F) in an amount of less than 0.005 percent by mass would be ineffective in anti-wear properties, while Component (F) in an amount of more than 0.2 percent by mass would deteriorate the oxidation stability.

The lubricating oil composition of the present invention preferably contains Component (G), i.e., boron-free ashless dispersants with the objective of improving wet friction characteristics, friction characteristics for wet clutches, inhibition of deterioration by oxidation while a lubricating oil is used, and dispersibility of insolubles.

Boron-free ashless dispersants which may be added are ashless dispersants which are compounds before

being modified with a boron compound as described with respect to Component (E). In the present invention, one or more kinds of compounds selected from such ashless dispersants may be blended in an arbitrary amount. The content of boron-free ashless dispersants is preferably from 0.1 to 10 percent by mass, based on the total mass of the lubricating oil composition.

Component (H), i.e., metal detergents other than Component (B), which may be used in combination with the lubricating oil compositions of the present invention may be any compounds which are usually used as metal detergents in a lubricating oil. For example, there may be used alkali metal or alkaline earth metal sulfonates, alkali metal or alkaline earth metal phenates, and alkali metal or alkaline earth metal naphthenates. One or more these compounds may be used in combination. Examples of alkali metals include sodium and potassium, while examples of alkaline earth metals include calcium and magnesium. Specific preferred examples of the metal detergents are calcium sulfonate, magnesium sulfonate, calcium phenate, and magnesium phenate. The base number and blend amount of these metal detergents are arbitrarily selected depending on the requisite performance characteristics of a lubricating oil.

Component (I), i.e., friction modifiers which may be used in combination with the lubricating oil compositions of the present invention may be any compounds which are usually used as friction modifiers in a lubricating oil. For example, there may be used amine compounds, fatty acid esters, fatty acid amides, and fatty acid metal salts, all having in the molecules at least one alkyl or alkenyl group having 6 to 30 carbon atoms, preferably at least one straight-chain alkyl or alkenyl group having 6 to 30 carbon atoms.

Examples of amine compounds include straight-chain or branched, preferably straight-chain aliphatic monoamines having 6 to 30 carbon atoms, straight-chain or branched, preferably straight-chain aliphatic polyamines having 6 to 30 carbon atoms, and alkyleneoxide adducts of these aliphatic amines. Examples of fatty acid esters include esters of straight-chain or branched, preferably straight-chain fatty acids having 7 to 31 carbon atoms and aliphatic monohydric alcohols or aliphatic polyhydric alcohols. Examples of fatty acid amides include amides of straight-chain or branched, preferably straight-chain fatty acids having 7 to 31 carbon atoms and aliphatic monoamines or aliphatic polyamines. Examples of fatty acid metal salts include alkaline earth metal salts (magnesium salts and calcium salts) or zinc salts of straight-chain or branched, preferably straight-chain

fatty acids having 7 to 31 carbon atoms.

Although in the present invention, one or more compounds selected from the above-described friction modifiers may be blended in an arbitrary ratio, the content of thereof is generally within the range of 0.01 to 5.0 percent by mass, preferably 0.03 to 3.0 percent by mass, based on the total amount of the lubricating oil composition.

Component (J), i.e., anti-oxidants which may be used in combination with the lubricating oil compositions of the present invention may be any conventional ones such as phenol-based compounds or amine-based compounds which are usually used as anti-oxidants for a lubricating oil.

Specific examples of oxidation inhibitors include alkylphenols such as 2-6-di-tert-butyl-4-methylphenol; bisphenols such as methylene-4,4-bisphenol(2,6-di-tert-butyl-4-methyl phenol); naphtylamines such as phenyl-α-naphtylamine; dialkyldiphenylamines; zinc dialkyldithiophosphates such as zinc di-2-ethylhexyldithiophosphate; and esters of (3,5-di-tert-butyl-4-hydroxyphenyl)fatty acid such as propionic acid and monohydric or polyhydric alcohols such as methanol, octadecanol, 1,6-hexanediol, neopentyl glycol, thiodiethylene glycol, triethylene

glycol, and pentaerythritol.

Although in the present invention, one or more compounds selected from the above-described anti-oxidants may be blended in an arbitrary ratio, the content of thereof is generally within the range of 0.01 to 5.0 percent by mass, based on the total amount of the lubricating oil composition.

Component (K), i.e., viscosity index improvers which may be used in combination with the lubricating oil compositions of the present invention may be non-dispersion type viscosity index improvers such as polymers or copolymers of one or more monomers selected from various methacrylates or hydrides thereof and dispersion type viscosity index improvers such as copolymers of various methacrylates further containing nitrogen compounds. Another examples of viscosity index improvers are non-dispersion- or dispersion-type ethylene-α-olefin copolymers of which the α-olefin may be propylene, 1-butene, or 1-pentene, or the hydrides thereof, polyisobutylenes or the hydrogenated products thereof, styrene-diene hydrogenated copolymers, styrene-maleate anhydride copolymers, and polyalkylstyrenes.

It is necessary to select the molecular weight of these viscosity index improvers considering the shear stability thereof. Specifically, the number-average

molecular weight of non-dispersion or dispersion type polymethacrylates is preferably from 5,000 to 150,000, and more preferably from 5,000 to 35,000. The number-average molecular weight of polyisobutylenes or hydrides thereof is from 800 to 5,000, preferably from 1,000 to 4,000. The number-average molecular weight of ethylene-α-olefin copolymers and hydrides thereof is from 800 to 150,000, preferably from 3,000 to 12,000.

Among these viscosity index improvers, the use of ethylene-α-olefin copolymers or hydrides thereof is contributive to production of a lubricating oil composition which is excellent particularly in shear stability.

Although in the present invention, one or more compounds selected from the above-described viscosity index improvers may be blended in an arbitrary ratio, the content of thereof is generally within the range of 0.1 to 40 percent by mass, based on the total amount of the lubricating oil composition.

Component (L), i.e., anti-foamers which may be used in combination with the lubricating oil compositions of the present invention may be any conventional ones which are usually used as anti-foamers for a lubricating oil. Specific examples of anti-foamers include silicones such as dimethylsilicone and fluorosilicone. Although in the

present invention, one or more compounds selected from the above-described anti-foamers may be blended in an arbitrary ratio, the content of thereof is generally within the range of 0.001 to 0.05 percent by mass, based on the total amount of the lubricating oil composition.

Examples of Component (M), i.e., rust preventives include alkenyl succinic acids, alkenyl succinic acid esters, polyhydric alcohol esters, petroleum sulfonates, and dinonylnaphthalenesulfonate.

Examples of Component (N), i.e., corrosion inhibitors include benzotriazole-, tolyltriazole-, and imidazole-based compounds.

Examples of Component (O), i.e., pour-point depressants include polymethacrylate-based polymers, which are adaptable to a lubricating base oil to be used.

Examples of Component (P), i.e., rubber swelling agents include aromatic compounds.

In the present invention, the contents of Components (M), (N), (O), and (P) may be arbitrarily selected. However, in general, the content of the corrosion inhibitors, is from 0.005 to 0.2 percent by mass, based on the total mass of the composition. The content of the other additives is from 0.005 to 10 percent by mass, based on the total mass of the composition.

[Best Mode for Carrying out the Invention]

The present invention will be further described in more detail with reference to the following examples and comparative examples but are not limited thereto.

(Examples 1 to 8 and Comparative Examples 1 to 8)

There were prepared transmission lubricating oil compositions (Examples 1 to 8) as shown in Tables 1-1 and 1-2 and those for comparison (Comparative Examples 1 to 8) as shown in Tables 2-1 and 2-2. Each of the compositions was evaluated by (1) a duration test of anti-shudder properties and (2) a fatigue life test described below. The results are also shown in Tables 1-1, 1-2, 2-1, and 2-2.

(1) Duration test of anti-shudder properties

On the basis of "Automatic transmission fluids-Anti-shudder performance test" prescribed in JASO M349-98, the low velocity sliding test wherein the fluid temperature during the duration test was changed from 120 ℃ to 140 ℃ was conducted. The duration of anti-shudder properties was evaluated with a ratio of the duration of the reference oil used in the above test to that of each of the compositions in Examples and Comparative Examples.

The measurement was conducted for each composition every 24 hours after 0, 6, 12, and 24 hours.

If the duration of a composition was equal to or longer (72 hours or longer) than that of the reference oil, the composition was judged to be excellent in duration of anti-shudder properties. In the case where the duration was 4 times (288 hours) or longer than that of the reference oil, the test was discontinued, the evaluation was indicated by 4 or more.

(2) Fatigue life test

The fatigue life of each of the compositions was measured using a two cylinder-type fatigue tester in the following manner.

(Cylinder)

Material: SCM436

Shape : Φ 68 mm x 10 mm

Hardness: SB3000 to 340

(Test conditions)

Peripheral velocity: driving side: 12 m/s,
driven side: 10 m/s

Oil temperature: 60 ℃

Surface pressure: 12 MPa

(Evaluation criterion)

Time consumed until surface damages such as pitching appear was evaluated as fatigue life. If the fatigue life of the composition is 50 hours or longer, the composition was evaluated as having a long fatigue life.

Table 1-1

			Example 1	Example 2	Example 3	Example 4
(A) Base oil	Refined mineral oil (Base oil viscosity @100°C 4.0mm^2/s)	mass%[2)]	100	100	100	100
	Refined mineral oil (Base oil viscosity @100°C 2.6mm^2/s)	mass%[2)]	-	-	-	-
	Poly-α-olefin (Base oil viscosity @100°C 2.6mm^2/s)[1)]	mass%[2)]	-	-	-	-
	Refined mineral oil (Base oil viscosity @100°C 31mm^2/s)	mass%[2)]	-	-	-	-
	Adjusted base oil viscosity	mm^2/s	4	4	4	4
(B) Calcium salicylate (BN=170mgKOH/g)		mass% (Ca concentration)[3)]	0.007	0.03	0.06	0.03
(C) SP type extreme pressure additive	Trilaulyltrithiophosphite	mass% (P concentration)[3)]	0.02	0.02	0.02	-
	Trilaulyldithiophosphite	mass% (P concentration)[3)]	-	-	-	0.02
	Di(2-ethylhexyl) dithiophosphate	mass% (P concentration)[3)]	-	-	-	-
Phosphorus-based additive	Di(2-ethylhexyl) phosphite	mass% (P concentration)[3)]	0.01	0.01	0.01	0.01
(D) Succinimide	Succinimide A[4)]	mass%[3)]	2	2	2	2
	Succinimide B[5)]	mass%[3)]	-	-	-	-
(E) Ashless dispersant	Boron-free ashless dispersant[6)]		2	2	2	2
	Boron-containing ashless dispersant[7)]	mass% (B concentration)[3)]	0.005	0.005	0.005	0.005
Other additives[8)]		mass%[3)]	8	8	8	8
(1) Fatigue life		hours	96	102	98	98
(2) Anti-shudder property durability ratio between the composition and the reference oil (72hours)			4<	4<	4<	4<

1) prepared by mixing poly-α-olefin of 1.8mm^2/s @100°C and poly-α-olefin of 4mm^2/s @100°C

2) based on the total mass of base oil

3) based on the total mass of composition

4) diethylenetriamine bis(iso-octadecenyl) succinimide

5) tetraethylenepentamine bis(iso-octadecenyl) succinimide

6) polybutenyl succinimide (bis type, weight-average molecular weight of polybutenyl group: 1,000)

7) boric acid-modified polybutenyl succinimide (bis type, boron content: 0.5mass%, weight-average molecular weight of polybutenyl group: 1,300)

8) anti-oxidant (amine-based, phenol-based), seal swelling agent (aroma-based), friction modifier (amine-based + ester-based), viscosity index improver, and pour-point depressant (polymethacrylate-based)

Table 1-2

				Example 5	Example 6	Example 7	Example 8
(A) Base oil	Refined mineral oil (Base oil viscosity @100°C 4.0mm^2/s)		mass%[2]	100	100	-	-
	Refined mineral oil (Base oil viscosity @100°C 2.6mm^2/s)		mass%[2]	-	-	75	-
	Poly-α-olefin (Base oil viscosity @100°C 2.6mm^2/s)[1]		mass%[2]	-	-	-	75
	Refined mineral oil (Base oil viscosity @100°C 31mm^2/s)		mass%[2]	-	-	25	25
	Adjusted base oil viscosity		mm^2/s	4	4	4	4
(B) Calcium salicylate (BN=170mgKOH/g)			mass% (Ca concentration)[3]	0.03	0.03	0.03	0.03
(C) SP type extreme pressure additive		Trilaulyltrithiophosphite	mass% (P concentration)[3]	-	0.02	0.02	0.02
		Trilaulyldithiophosphite	mass% (P concentration)[3]	-	-	-	-
		Di(2-ethylhexyl) dithiophosphate	mass% (P concentration)[3]	0.02	-	-	-
Phosphorus-based additive		Di(2-ethylhexyl) phosphite	mass% (P concentration)[3]	0.01	0.01	0.01	0.01
(D) Succinimide		Succinimide A[4]	mass%[3]	2	-	2	2
		Succinimide B[5]	mass%[3]	-	2	-	-
(E) Ashless dispersant		Boron-free ashless dispersant[6]		2	2	2	2
		Boron-containing ashless dispersant[7]	mass% (B concentration)[3]	0.005	0.005	0.005	0.005
Other additives[8]			mass%[3]	8	8	8	8
(1) Fatigue life			hours	102	108	120<	120<
(2) Anti-shudder property durability ratio between the composition and the reference oil (72hours)				4<	4<	4<	4<

1) prepared by mixing poly-α-olefin of 1.8mm^2/s @100°C and poly-α-olefin of 4mm^2/s @100°C

2) based on the total mass of base oil

3) based on the total mass of composition

4) diethylenetriamine bis(iso-octadecenyl) succinimide

5) tetraethylenepentamine bis(iso-octadecenyl) succinimide

6) polybutenyl succinimide (bis type, weight-average molecular weight of polybutenyl group: 1,000)

7) boric acid-modified polybutenyl succinimide (bis type, boron content: 0.5mass%, weight-average molecular weight of polybutenyl group: 1,300)

8) anti-oxidant (amine-based, phenol-based), seal swelling agent (aroma-based), friction modifier (amine-based + ester-based), viscosity index improver, and pour-point depressant (polymethacrylate-based)

Table 2-1

			Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4
(A) Base oil	Refined mineral oil (Base oil viscosity @100°C 4.0mm^2/s)	mass%[1]	100	100	100	100
(B) Calcium salicylate (BN=170mgKOH/g)		mass% (Ca concentration)[2]	0.09	-	0.03	0.03
(C) SP type extreme pressure additive	Trilaulyltrithiophosphite	mass% (P concentration)[2]	0.02	0.02	0.1	-
Phosphorus-based additive	Di(2-ethylhexyl) phosphite	mass% (P concentration)[2]	0.01	0.01	0.01	0.03
Sulfur-based additive	Polyisobutylene sulfide (S content 45mass%)	mass%[2]	-	-	-	-
	Sulfated fat (Sulfated lard, S content 30mass%)	mass%[2]	-	-	-	-
(D) Succinimide	Succinimide A[3]	mass%[2]	2	2	2	2
(E) Ashless dispersant	Boron-free ashless dispersant[4]	mass%[2]	2	2	2	2
	Boron-containing ashless dispersant[5]	mass% (B concentration)[2]	0.005	0.005	0.005	0.005
Other additives[6]		mass%[2]	8	8	8	8
(1) Fatigue life		hours	52	18	26	32
(2) Anti-shudder property durability ratio between the composition and the reference oil (72hours)			0.33	0.67	0.33	4<

1) based on the total mass of base oil

2) based on the total mass of composition

3) diethylenetriamine bis(iso-octadecenyl) succinimide

4) polybutenyl succinimide (bis type, weight-average molecular weight of polybutenyl group: 1,000)

5) boric acid-modified polybutenyl succinimide (bis type, boron content: 0.5mass%, weight-average molecular weight of polybutenyl group: 1,300)

6) anti-oxidant (amine-based, phenol-based), seal swelling agent (aroma-based), friction modifier (amine-based + ester-based), viscosity index improver, and pour-point depressant (polymethacrylate-based)

Table 2-2

			Comparative Example 5	Comparative Example 6	Comparative Example 7	Comparative Example 8
(A) Base oil	Refined mineral oil (Base oil viscosity @100°C 4.0mm²/s)	mass%[1]	100	100	100	100
(B) Calcium salicylate (BN=170mgKOH/g)		mass% (Ca concentration)[2]	0.03	0.03	0.03	0.03
(C) SP type extreme pressure additive	Trilaulyltrithiophosphite	mass% (P concentration)[2]	-	-	0.03	0.03
Phosphorus-based additive	Di(2-ethylhexyl) phosphite	mass% (P concentration)[2]	0.01	0.01	0.01	0.01
Sulfur-based additive	Polyisobutylene sulfide (S content 45mass%)	mass%[2]	0.2	-	-	-
	Sulfated fat (Sulfated lard, S content 30mass%)	mass%[2]	-	0.2	-	-
(D) Succinimide	Succinimide A[3]	mass%[2]	2	2	-	2
(E) Ashless dispersant	Boron-free ashless dispersant[4]	mass%[2]	2	2	2	3
	Boron-containing ashless dispersant[5]	mass% (B concentration)[2]	0.005	0.005	0.005	-
Other additives[6]		mass%[2]	8	8	8	8
(1) Fatigue life		hours	120<	120<	96	48
(2) Anti-shudder property durability ratio between the composition and the reference oil (72hours)			0.33	0.33	0.17	2

1) based on the total mass of base oil

2) based on the total mass of composition

3) diethylenetriamine bis(iso-octadecenyl) succinimide

4) polybutenyl succinimide (bis type, weight-average molecular weight of polybutenyl group: 1,000)

5) boric acid-modified polybutenyl succinimide (bis type, boron content: 0.5mass%, weight-average molecular weight of polybutenyl group: 1,300)

6) anti-oxidant (amine-based, phenol-based), seal swelling agent (aroma-based), friction modifier (amine-based+ester-based), viscosity index improver, and pour-point depressant (polymethacrylate-based)

As apparent from the results shown in Tables 1-1 and 1-2, the lubricating oil compositions of Examples 1 to 8 had long duration of both anti-shudder properties and anti-pitching properties. As seen particularly from Examples 7 and 8 wherein a heavy base oil with a high kinematic viscosity is blended, the resulting lubricating oil compositions had further prolonged duration of anti-pitching properties.

On the other hand, the composition containing too much Component (B), i.e., calcium salicylate (Comparative Example 1) was poor in duration of anti-shudder properties, and the composition containing no Component (B) (Comparative Example 2) was poor in duration of anti-pitching properties. The composition containing too much Component (C), i.e., SP type extreme pressure additive (Comparative Example 3) was satisfactory in duration of neither anti-shudder properties nor anti-pitching properties. The compositions containing no Component (C) (Comparative Examples 4 to 6) failed to achieve long-lasting anti-pitching properties and anti-shudder properties at the same time. The composition containing no Component (D), i.e., succinimide (Comparative Example 7) was poor in duration of anti-shudder properties, while the composition containing no Component (E), i.e., boron-containing ashless dispersant (Comparative Example 8) was poor in duration of anti-pitching

properties.

[Effects of the Invention]

The lubricating oil composition of the present invention has excellent duration of anti-shudder properties and capable of providing long fatigue life. Therefore, the lubricating oil composition of the present invention can be used as a transmission oil, particularly as a lubricating oil composition for automatic transmissions and/or continuously variable transmission or transmissions equipped with a wet clutch and/or wet brake as well as a lubricating oil required to prevent pitching so as to improve fatigue life, such as a gear oil, a lubricating oil for internal combustion engines, a hydraulic oil for shock absorbers, and a compressor oil.